

III. *Observations on the Affinity between Basaltes and Granite.*

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ALL our opinions on the formation of rocks and mountains, except volcanic mountains, must of necessity rest upon analogical reasoning, since we have no direct testimony concerning their origin. Hence, whatever portion of the mineral kingdom is but little connected with our experience of the action of fire or water, must be slightly passed over, or set aside for future investigation, while the partizans of the two opposite hypotheses, which at present divide the philosophical observers of fossils, fix their whole attention, and lay all the stress of their arguments, on such particulars as they are able to connect by some analogy with the chemical operations in which either fire or water are principally concerned. For this reason, basaltes has been much more the subject of disputation than granite; the former species of rock offering appearances that coincide in some degree with both kinds of chemical processes, while the latter seems to stand aloof from the experiments that have given birth to our sciences. We do, indeed, find opinions on the production of granite by one or other of the causes above mentioned; but they are generally * loose conjectures, thrown out at random, rather than philosophical propositions, laid down in precise

* The only exceptions known to me are, Phil. Transf. Vol. LXV. p. 5—47. and Edinburgh Transactions, Vol. I. p. 255—257.

terms, and supported by proper evidence. In consequence of information obtained from various sources, I have been led to consider this question in a light somewhat new; and although I cannot but expect my conclusions to be controverted, however strong may be my own conviction of their justness, I am encouraged by the hope of communicating some original observations on the physical geography of our own country, and of bringing forward to public notice some facts not generally known among us, though they are such as cannot be overlooked in a theory of granite.

Notwithstanding the recent objections of Mr. WERNER *, I shall assume the origin of basaltcs from subterraneous fusion as thoroughly established by various authors †. Several observations of my own, which I intend soon to offer to the publick, will, I flatter myself, corroborate the evidence, though already sufficiently strong to remove all reasonable doubt, and add a considerable tract to those where the effects of ancient fire have

* *Bergmännisches Journal*, March 1789. Among the facts adduced by this celebrated mineralogist to prove the watery origin of basaltcs, I cannot discover any very new or striking. The appearance of basaltcs between strata is his great argument. But the same, or a similar appearance had been noticed by Dr. HUTTON (*Edinb. Tr.* I. p. 279.); WHITEHURST (*Chap. XVI.*): FERBER (*Italy*, p. 51.) mentions the insertion of lava between calcareous strata; and in LESKE (*Reise durch Sachsen*, 4to, 1785, p. 517.), we have basaltic columns in sandstone. Mr. WERNER also insists upon the gradual approximation of the adjacent stratum towards the nature of basaltcs.

† DESMAREST, in his well-known Paper in the French Memoirs; RASPE, *Extinct Volcanos near Cassel*; FAUJAS, *Volcans éteints*, &c. and *Minéralogie des Volcans*; Sir W. HAMILTON, *Campi Phlegreæ*, and *Phil. Trans.*; FERBER, *Travels through Italy*; DOLOMIEU, in his *Account of the Lipari and Pontian Idcs*; LESKE, *l. c.*; BEROLDINGEN, in his *Account of the Quicksilver Mines in the Palatinate*, &c.; HAMILTON, *Letters on the Coast of Antrim*; HUTTON, *l. c.*; VELTHEIM, *Etwas über die Basalt*, Leipzig, 1787; are among the chief of these authors.

been traced in our times. It may be proper to premise, that under the term basalt^{es} I comprehend that vast natural family of rocks which is frequently cracked into regular colonnades, and may be followed in an unbroken series from this perfect form through endless modifications to the most shapeless mass of trapp or whinstone. Though frequently of an iron-grey colour and uniform texture, this species of stone varies greatly in both these characters, even in the same rock. In particular, it passes, by the most insensible gradations, both to the porphyries, with which it coincides in appearance, in composition, and doubtless also in origin, and to the *bornstein* of the Germans; a term including petrosilex and several sorts of close grained whinstone, of which I have found in England varieties with a conchoidal fracture, semi-transparent at the edges, and in other respects fast approaching * to a siliceous nature. Lilleshall Hill near Shifnal, in Shropshire, to mention a single instance, affords such siliceous, besides *semi-granitic*, porphyritic, and common whinstone, containing agate.

But basalt^{es}, of which a right knowledge is conducting us fast to a just theory of the earth, is not less connected with granite; *insomuch that we may trace these rocks gradually approaching and changing into one another*. I have myself had an opportunity of examining many connecting links in this gradual succession; and this opinion, which has since been confirmed by other considerations, was first forced upon me by specimens in great variety from volcanic and basaltic countries. But as it is a point by far too important to be admitted on the mere authority of any mineralogist, I shall endeavour to support it by the testimony of observers, who cannot be suspected

* DOLOMIEU, *Isles Ponce*, p. 111. 185. &c. describes just such lavas.

of any bias towards such an hypothesis. The first step in the progression appears at the Giant's Causeway in Ireland. Many of the pillars there consist of fine-grained, dark-coloured whinstone; that variety which may be considered as most perfect, and as equidistant from porphyry, petrosilex, and granite; but at the promontory of Fairhead, the character of the stone is seen to alter, and it has lately been described as an imperfect kind of granite*. Hence we are led by regular approaches to perfect prisms of granite, accompanied by prisms of common whinstone, and not less obviously than the different ranges on the Coast of Antrim betraying a common origin. The pillars of Les Rameaux, though they rather incline towards the dark colour and uniform hard substance; "yet, when broken, are unequal both in colour and texture, "and sometimes interspersed with irregular pieces and patches, "as it were, of an heterogeneous hard substance, which, by "its micæ and small rhomboidal crystallizations, much resembles a sort of granite I have frequently seen. The "mass on which these columns stand is of the same mixed "character †." Other examples will occur afterwards; and for basaltiform colonnades of granite it is only necessary to refer to Mr. STRANGE's description of Monte Rosso ‡. The general shape of the Euganean hills, as if suddenly raised by

* HAMILTON, 2d edition of his Letters, p. 37. says, it "resembles an imperfect compact granite." I have specimens from an hill near Mallwhyd, in the vicinity of Cader Idris, where the texture insensibly changes from an uniform whinstone ground to grains of mica, feldspath, shoerl, and, I think, sometimes quartz. They are, I fancy, like those dense lavas of Etna, "Qui, vues à la loupe, laissent appercevoir des ébauches de crystallization de shörl, de quarz, ou de feld-spath. DOLOMIEU, *l. c.* p. 182.

† STRANGE, Phil. Trans. LXV. p. 13.

‡ Ibid.

the expansive and effervescent force of heat * from the surrounding plain, the lava intermixed with granite, as if both had concreted together, the columns of an uniform texture in the adjacent parts of these hills, and the rest of the phænomena, even then led the author to suspect, “a strong analogy between granites and many particular volcanic concretions.”

From the mountain of Esterelles, in the South of France, on the road from Frejus to Antibes, I have before me granite, gneiss, and specimens, in which feldspath and grains of transparent quartz are diffused through a paste of the same brownish red colour and texture as the basaltic columns at Dunbar in Scotland.

Nothing is indeed more common, or more variously modified, than fossils of this intermediate character †. We frequently find a ground of jasper, and no doubt also of different varieties of whinstone, as will hereafter appear, with feldspath and shoerl at the same time imbedded in them ‡; and again with grains of feldspath and quartz in such a manner as to leave it extremely doubtful, whether the rock ought to be named granite or porphyry §. The varieties of such rocks will conduct us, by easy steps, from uniform basaltes through the porphyries to granite. A chemical examination of the basis of a number of these porphyries would be very interesting; yet I would not rest the theory of their formation altogether on the result of analysis.

* The sight of them impressed FERBER also with the same idea.

† Il n'y a point de naturalistes qui ne connoissent le genre de roches, placé entre le granit, les gneiss, et les porphyres, qui tiennent un peu des trois especes. *Iles Ponces*, p. 90.

‡ HAIDINGER, *Traët* quoted below, p. 47.

§ CHARPENTIER (*Mineralogical Geography of Saxony*, 4to, 1778. in German), p. 50. and elsewhere, finds himself in this state of uncertainty.

The same stratum is perpetually varying in its mixture; and we should not too rigourously adhere to the proportion of ingredients discovered by the chemist in the hundred grains upon which his experiments may chance to be made. The sensible qualities, the stile of fissure, the accompanying fossils, and the form of whole rocks, when surveyed by an experienced eye, are as good criterions of basaltes as a certain proportion of iron, and the black glass which it yields on fusion. Should the matter of any given rock contain too little iron to be fusible by the blow-pipe, and yet have other striking features of whinstone, would this be a sufficient reason to conclude, that its formation has been different? Chemistry, if thus strictly followed, would perplex mineralogy, instead of reducing it to order. Characters of minerals, purely chemical, would separate those whose natural history is alike, and bring together such as differ widely in their formation.

The late Mr. FERBER's letters from Italy furnish so many facts, conspiring in one way or another to shew the affinity between basaltes as well as other products of subterraneous fire and granite, that whoever reads them with this view will, I am persuaded, find himself more interested and instructed. The following are among the most striking of these facts.

“ 4th species of basaltes. Oriental basaltes through which
“ the constituent parts of granite are equably diffused. Sepa-
“ rate particles of red feldspath, quartz, and mica, are
“ dispersed through the substance of this species: they seem to
“ have been distributed through an aqueous solution, and to
“ prove, that this species had rather an aqueous than a fiery
“ origin.” I see neither proof nor presumption in favour of
this supposition; but in a series of specimens, collected with a

view

view to shew the transition from black basalt to granite, this species and the granite from Esterelles would form two contiguous links.

“ 5th Oriental basalt, with stripes of granite. The common black basalt, fasciated with large stripes of red granite, blended and joined to the basalt without any visible separation; not as the pebbles in a breccia, or as fissures healed up and filled with granite, but as if both the basalt and granite had been fluid together *.”

Those specimens, which shew how copiously volcanos produce feldspar, horn, and mica, especially the two former (substances common both to basalt and granite), tend greatly to establish the near relation between these two kinds of rock. I was surprized, at this day, to find an excellent observer seriously maintaining, that these earthy crystallizations are merely ejected, and not generated, by these fires †.

Attempts, I am aware, have been made to set up boundaries between the columnar granite of the Euganean hills, the granite of the volcanic provinces of France, the granitello of the Italians, and such granite as is found to constitute high and extensive ranges of mountains. As to a difference in the size of particles, and hardness of the stone, the first distinction is neither constant, nor by any means calculated to persuade us, that a cause, capable of producing the one, is inadequate to the production of the other. It may probably be explained from the quantity of matter, more or less perfect fusion, a different length of time in cooling; and in the latter character I suspect the observers to have been deceived by the

* See FERBER's Travels in Italy, pp. 231, 232. English translation.

† DOLOMIEU, Isles Poncees, and Laves de l'Etna, passim.

decay of the rocks they inspected*. At all events, lavas in abundance shew, that fire is capable of producing any required degree of compactness †.

I shall conclude this induction of particulars with an observation lately published by one of our most intelligent mineralogical travellers. “ Among the ancient black stones, the
“ compound species are most frequent. They often consist of
“ *a kind of granite*, in which the scaly black shoerl predominates
“ so much, that the whole mass appears black. It is accompa-
“ nied by white feldspath of so small a grain, and so entangled
“ among the shoerl, as to be sometimes scarcely distinguishable.
“ The feldspath itself is sometimes transparent, and by trans-
“ mitting the colour of the shoerl, in which it is imbedded
“ (*empâté*) appears black Sometimes scales of black
“ mica occur. The constituent parts do not always observe
“ the same proportion; and when the quantity of feldspath
“ increases, the appearance of a real grey or red granite is pro-
“ duced. Hence we have veins and spots of grey granite in
“ almost all the dark-coloured rocks that pass under the
“ denomination of basaltes. These veins have very much
“ embarrassed those naturalists who maintain that all basaltes
“ has been produced by fire.” This circumstance, however, according to my view of the subject, is far from embarrassing: I consider it as a strong proof of my opinion, since it seems to involve this consequence, that, if basaltes proceed from fusion, granite also must. Specimens, such as those here described, I should place near granular basaltes, like that of Cape Fairhead. “ In blocks of ancient basaltes,” proceeds M. DOLO-

* “ Though partial spots of this granite are often friable, especially about the surface, yet in general it is very hard.” STRANGE, *ubi supra*, p. 9.

† See DOLOMIEU, *Isles Ponce*, p. 139.

MIEU, "I have observed the transition from shoerl in a
 " mafs nearly homogeneous (I fay, *nearly homogeneous*, be-
 " cause I know of no ftones, belonging, as thefe do, to the
 " primitive mountains, without indications of a feparation of
 " feveral fubftances which were incorporated together in a
 " pafte, or rather which are generated in that pafte) to black
 " and white granites, with large grains, and compofed of
 " nearly equal quantities of white feldfpath and black shoerl.
 " The transition depends altogether on an increafed proportion
 " of feldfpath and on the enlargement of its grains; a
 " phænomenon which leaves no room to doubt, that all thefe
 " ftones belong to the fame fyftem of mountains *."

By obfervations like thefe, which the fpecimens I either poffefs, or have examined, corroborate and compleat, I am perfuaded, that when once it becomes an object of attention, perfons who have an opportunity of exploring countries where bafaltes and granite abound, will eafily find a fucceffion of fpecimens beginning at the former and terminating at the latter. Nor is it perhaps difficult to affign highly probable reafons, why a mixture of different earths with more or lefs of metallic matter, in returning from a ftate of fufion to a folid confiftence, may affume fometimes the homogeneous *basaltic*, and fometimes the heterogeneous *granitic* internal ftructure. No fact is more familiar than that it depends altogether on the management of the fire, and the time of cooling, whether a mafs fhall have the uniform vitreous fracture, or an earthy broken grain, arifing from a confufed cryftallization. The art of making REAUMUR's porcelain confifts en-

* Journal de Phyfique, September 1790, p. 196. I have feveral fpecimens from the whin rocks about Edinburgh perfectly anfwering to this defcription, and fo like fome Vefuvian lavas that it is impoffible to diftinguifh them.

tirely in allowing the black glass time to crystallize by a slow refrigeration; and the very same mass, according as the heat is conducted, may, without any alteration of its chemical constitution, be successively exhibited any number of times as glass, or as a stony matter with a broken grain. In the slag of the iron furnaces, the same piece generally exhibits both these appearances; the upper surface cools fast, and is glass; what lies deeper, loses its heat more gradually, and is allowed time to take on the crystalline arrangement peculiar to its nature, in as far as a number of crystals, starting from various points at once, and crowding each other, will admit of it. Here indeed the crystals are uniform, and not of a different form and composition, as in granite; so that this analogy applies closely only to basaltes; and it perfectly explains why this body in congealing has assumed an earthy and not a vitreous grain. But it is easy to conceive how, under certain variations of heat and mixture, a melted mass may coagulate into quartz, feldspath and shoerl, or mica*. The most permanent difference between basaltes and granite, as to mixture, consists in the quantity of iron; for the earths in the innumerable varieties of each vary indefinitely in their proportions; and as to heat, that the latter having been perhaps in general raised from a greater depth, and consisting of more

* “ Il est certain que dans les porphyres les cristaux de feld-spath n'existoient pas avant l'époque de la précipitation de leur base.” He supposes them to be of aqueous origin; but the fact is much to my present purpose. “ On y suit les progrès successifs de leur formation: on voit que peu à peu les substances qui leur sont propres se rapprochent, s'épurent et prennent les formes qui conviennent à leurs molécules; ils étoient comme en dissolution dans leurs matrices et ils ont d'autant plus de facilité à se joindre que la fluidité a été plus parfaite et que le dessèchement a été plus long.” *Iles Poncees*, 247, 248.

huge masses, must have cooled more slowly, and perhaps they have undergone different degrees of fusion. Besides toadstone, basalt, enclosing feldspath, zeolite, &c., various lavas clearly demonstrate that heterogeneous earthy crystals do separate from a fused paste, once undoubtedly as uniform as a metallic calx and its reducing flux before the subsidence of the metallic particles. We shall, I imagine, be much deceived by a narrow analogy if, because in our processes for glass-making an homogeneous product is obtained from heterogeneous materials, we conclude, that an heterogeneous product may not, under other circumstances, result from fusion; and that fire keeps inseparably blended whatever it has once reduced to an uniform liquid paste.

It must also be carefully remembered, that this difficulty does not press the igneous more than the opposite hypothesis. Since the constituent parts of granite are crystals, the whole mass must once have existed in that state of entire disunion of its particles which is necessary to crystallization. Now, whether such a solution have been effected by the repulsive power of fire, or the intervention of water, it is just as easy to conceive heterogeneous earthy crystals shooting from different points of an uniform liquid, according to the former supposition, as the latter.

In the natural history of granite and basalt, another striking circumstance occurs: *they lie so contiguous, and are so involved in one another, that we cannot but suppose both to have undergone the same operations of nature at the same time.* This is seen with the utmost frequency upon every possible scale, and under a vast variety of modifications. The facts already quoted afford instances in point. I have before me a specimen from the park at Stockholm, consisting partly of trapp and partly of granite. The adjacent parts are as firmly united as the other

parts of the specimen; and when a violent blow is struck, the trapp and granite do not separate, but the fracture takes some other direction. They seem in several places of the boundary to run into one another. The whole mountainous district surveyed by Mr. LESKE * with such scrupulous accuracy affords multiplied examples of the contiguity and connection between these different rocks. "From all these minute descriptions," says the Author, "it appears, that the base of the whole range consists of granite. On the declivity of the highest elevations, and on the solitary summits of the external chain, *corneous porphyry* lies upon the granite, out of which as well as the granite itself, and the sandstone at its foot, basaltes has been protruded by the force of subterraneous fire †." The manner of connection will appear from a few examples. The basaltes of the Spizberg ‡ has a granulated structure, and is imbedded in granite. The substance of the pillars of the Gikelsberg § is close and granular: in some pieces "I found the constituent grains of granite *little altered*." Of the columns of the Knorberg, "the substance is close, uneven, and consists of distinct grains: . . . large pieces of *imperfectly fused* granite are diffused through its substance. In the Whinstone of the Hochwald there are found pieces consisting of a mixture of white feldspath, quartz, and black shoerl ||." Again, in the Rauberg, the constituent parts of granite are so diffused through the basaltes,

* Reise durch Sachsen.

† Ibid. p. 513. "It is also remarkable, that granite in general throughout Velay and Auvergne is frequently intermixed with the basaltine and other common volcanic hills. I have observed the same in Italy." STRANGE, p. 14.

‡ Reise durch Sachsen, p. 328.

§ Ibid. p. 498.

|| Ibid. p. 515.

that the Author imagines the rock to be an imperfectly fused granite *. I rather consider these as instances of imperfectly crystallized granite, where some unfavourable circumstance has prevented the constituent parts from receding completely from one another. Experiments shew, that almost all granites melt into a black glass †; and perhaps it is no abuse of analogy, nor inconsistent with what I have already remarked, to conclude, that granite, in the state of imperfect fusion, should present a glassy substance, involving the more infusible parts of which this stone consists.

The Scheibenberg, near Königsbruck, consists of a stone which Mr. LESKE knows not whether to call hornstone ‡, or corneous porphyry §. From the description it appears plainly to be a whinstone. The colour is dark grey; it breaks into columnar fragments; is hard, fine-grained, and *sonorous*; little veins of quartz cross it in all directions, and it frequently becomes porphyritic, as enclosing crystals of feldspath. The Author himself is afterwards aware || of its affinity to basaltes, both in substance and from its assuming the columnar form. In this hill a mass of granite is found imbedded in the whinstone, and on all sides surrounded by it, and the mass of granite is in its turn in all directions intersected with veins and stripes of whinstone. Mr. LESKE is much struck by this mutual and intimate incorporation; but he makes no attempt to explain it. In some instances, he thinks an eruption has

* Reise durch Sachsen, p. 330.

† HAIDINGER's Eintheilung der Gebirgsarten. Wien, 1787, p. 11. and the Authors quoted there.

‡ Hornschiefer.

§ Ibid. p. 24—29. No chemical characters are given.

|| Ibid. p. 513, 514

broke out through the granite; and in others, is at pains to shew, that these substances are not thoroughly blended, as in the last example, and in that described by FERBER.

It may be said, and no doubt it sometimes happens, that shivers of granite, broken off by the violence of explosion, are licked up by melted matter as it moves along; thus, in volcanic breccias an older lava is inclosed in one more recent, and thus what is called primary is sometimes encased in secondary granite. But such an hypothesis is too narrow to embrace all the phænomena. It does not explain the incipient coagulation of the uniform paste into grains, and those the different grains of granite; nor the diffusion of the constituent parts of granite through the substance of basaltes; nor the fifth species described by Mr. FERBER.

In the whinstone rocks of England, which are far more numerous than is commonly supposed, I have frequently observed in the same hill, 1. homogeneous dark grey stone; 2. feldspath enclosed in this as in a paste; and, 3. the paste disappearing, and the whole becoming granular, and the grains heterogeneous. Besides feldspath, quartz is found in innumerable masses of varying magnitude * in many whinstone rocks, and as proper basaltes is but a confused mass of crystals of shoerl, we have all the ingredients of granite; and why

* In the Wrekin, Cader Idris, &c. numerous and large veins filled with quartz occur; but these have not been *secreted* from the substance of the rocks in which they lie. They, perhaps, shew this most siliceous ingredient of granite to have been near and in fusion at the same time. About Cader Idris I suspect an incorporation of granite and basaltes may be found. I have seen pieces of granite about that mountain which did not seem to have been far removed from the rock to which they belonged; but I had then no particular inducement to make an accurate examination.

may we not expect to find them incorporated together, and in every state of diffusion and separation?

Under this head I shall only remark further, that several late observations, from which it has been inferred, that certain extinct volcanos have been seated in the heart of granite*, seem to admit of a much more easy explanation, on the supposition that granite has crystallized from fusion. 1. Volcanic fires reach to a much greater depth than any at which we have had an opportunity of making observations. The focus in different instances may be seated at a different distance from the surface; but none are probably less than several miles at least deep. 2. The currents of granitic lava † in the Pontian isles leave little room to doubt of the power of subterraneous fire to produce this substance. To suppose them to be rocks of granite fused, but otherwise unchanged, and that even fissile rocks may be made to flow without losing their laminated structure; is as bold an assumption as can easily be taken up. In the great igneous processes of nature fire need not be imagined to act otherwise ‡

* DOLOMIEU, *Isles Ponces*, p. 30, 31. and *Isles de Lipari*, in various parts.

† DOLOMIEU, *l. c. passim*, and particularly p. 89—97. Instructive as the particular facts described by this excellent mineralogist always are, I must dissent from him both on the mode of action of volcanic fires, and on the production of zeolite and other crystals, in glandular rocks, for the reasons assigned here and below.

‡ “Le feu produit, dans les laves, une fluidité qui n’a aucun rapport avec la fluidité vitreuse que nous opérons Celui des volcans n’a point d’intensité; il ne peut pas même vitrifier les substances les plus fusibles . . . il produit la fluidité par une espèce de dissolution, par une simple dilatation qui permet aux parties de glisser les unes sur les autres (DOLOMIEU, *Avant-propos*, p. 8.). See also p. 84. Fire in a crucible produces fluidity no otherwise; and when there is this freedom of motion among the *particules*, how can we suppose the crystals of granite and the leaves of schistus to remain unmixed even in a current of lava?

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than in our small experiments; we actually see it producing glafs and cellular spongy scoriæ: when the products are of a different character, we must have recourse to accessory circumstances, and not violate the plainest rules of philosophising by attributing different effects to the same cause. The latent motive for such an extraordinary hypothesis may easily be divined; the observer took it for granted, that all granite is of aqueous formation; hence he was obliged to reason backwards from the unknown, that of the Alps for instance, to the known, instead of proceeding from the palpable effects of subterraneous fire by easy steps to a general theory of granite. When it is taken for granted, before examination, that granite cannot be formed by fire, there remains no resource but to say, that granitic * lavas are granite rocks fused, but not altered in the arrangement of their constituent parts. 3. Though the heat of volcanos be sometimes and in some places moderate; in others we have good reason to believe, that it exceeds any degree we can produce, except by means of factitious air; we are certain that it forms molten currents of petrosilex and flint exactly the same as our gun flints †.

If we admit this reasoning, the appearance of granite in the bosom of volcanic desolation may, if duly examined in all its circumstances, afford strong evidence of its production by fusion; and it is reasonable to conclude, that it was once covered to a considerable depth by erupted matters, which the course of

* “ Les laves blanches de l’Ile Ponce paroissent appartenir plus particulièrement au granit et aux roches feuilletées granitiques. On reconnoît les substances qui constituent ordinairement ce genre de roche composée dans presque toutes les matières blanches (volcaniques) de cette île; savoir, le quartz en grain, le mica noir écailleux et le feldspath plus ou moins pur. DOLOMIEU, *l. c.* p. 89.

† Idem *ibid.* p. 107.

time, and the injuries of the atmosphere, have removed; though I by no means deny that a volcano may force its way through pre-existing rocks of granite.

There is still another analogy between basalt and granite, more important to the theory of the earth, and less liable to controversy than either of the preceding. *In their situation, with respect to other rocks, we may observe the same law.* The general rule of super-position, reckoning from below upwards, is, 1. granite; 2. schistus; 3. limestone. This rule has been found to hold good by so many mineralogical travellers that, though it may not be absolutely universal, it must be allowed to prevail very extensively. Now, in this island there are numerous instances where basalt is substituted in the series instead of granite, and where it seems to alternate with granite as the substratum of other rocks. On the road from Dolgelly in Merionethshire, by Mallwyd and Cann's Office, through Llanfair to Welchpool, schistus appears always incumbent on whinstone, except sometimes when the latter is interjected between the strata, or squeezed up through fissures. In Wales the country is so hilly, that the limestone, if it existed, has probably been washed away; but on the confines of England it comes in. The road from Welchpool to Shrewsbury passes over the side of the Long Mountain, which consists of schistus; on the left, or towards the east, rise some considerable basaltic hills. The strata of the Long Mountain point towards the summit of these hills, as if the narrow valley that intervenes had been cut by water upon the lifted edge of the schistus. At a small distance from the north and south sides of the basaltic hills calcareous strata are found. Beyond Shrewsbury, on the road to London, we have, instead of the continued ridges of Wales, a number of insulated, and generally

generally rugged, points, rising over the face of Shropshire and the adjacent counties. Were the plains covered with water a few yards in depth, these eminences would appear from distance to distance like so many stepping stones. They all, except the Malvern Hills, which, though composed of granite, I consider as part of the same system, consist of whinstone. Among these stepping stones I reckon the basaltic hills near Welshpool, the Wrekin, Lilleshall Hill, and, at a greater distance towards the East, the rising grounds near Newcastle in Staffordshire, whence the whin rock, perhaps, communicates by the toadstone of Derbyshire, through the hills in the North of England with the whinstone towards the South of Scotland. In a south or south-west direction from the Wrekin, a number of craggy eminences arise. They are basaltes, and form a striking contrast with the smooth, rounded, and lumpish swells of schistus in their neighbourhood. From the whin rocks near Stretton we may pass by the Brown and Titterstone Clee Hills (on the latter of which are regular prismatic columns) to the Malvern Hills. About these hills lie strata of schistus and limestone, as is seen on the road from Much Wenlock to Stretton. To the south-east an extensive field of whinstone, with occasional elevations, is spread over the confines of Worcestershire, Warwickshire, and Staffordshire. Here we have the Rowley ragstone. Whether the basaltes proceeds southward by such interruptions till it join the Elvin or whinstone, and granite of Devonshire and Cornwall, where I imagine they may be found incorporated, I wish for an opportunity to examine. In the plain part of this whole district, the whin rock appears frequently at the surface, or a little below the strata, so that the hills have probably a subterraneous communication with one another, and there needed

but a little more lifting force to form continued ranges of mountains. The road from Welshpool to Birmingham, above three-score miles, is repaired in a great measure with whinstone. A colonnade of basalt has been lately exposed in digging the Shropshire canal; and in the mining country around, levels have been driven in the black rock, as it is sometimes called. As I have seen whinstone and slate in various other parts of North and South Wales, the whole western side of our island has probably been raised by the basalt on which the superficial strata now rest, though from particular circumstances the fused mass has now and then crystallized into granite; and as it has been conjectured, that the basalt of Ireland once joined that of the Scotch isles and the main land itself, so perhaps the basalt of North Wales joined the Irish coast till the sea worked its way or broke in, and destroyed the continuation.

As limestone is sometimes said to rest immediately on granite *, so at the foot of the Wrekin, and at Lilleshall Hill, no slate is interposed between the limestone and basalt; so that the analogy extends even to the exceptions.

But another series has been observed, which seems to connect granite by a closer tie with the operations of subterraneous fire. In Italy lava stands to slate and limestone in the same relation as granite and whinstone in other countries †. Whole ridges of mountains in the Venetian territory consist of solid lava, sometimes almost bare, sometimes retaining the superincumbent strata, with several local variations; all of which are reducible to a greater or less degree of lifting force. These

* BORN's Letters, p. 207.

† FERBER, *l. c.* pp. 42. 51.; and especially STRANGE, *l. c.* p. 24—32.

chains have a totally different form from the common conical shape of volcanos or heaps of loose ejected matters. They seem to afford a clear instance of the manner in which long continuations of mountains have been elevated; for it is not easy to admit the supposition of the observer, who has so accurately described them, that the limestone has been converted into lava; and that the ridges existed, such as they appear at this day, before this change was produced by subterraneous fire. Chemical and mechanical considerations are unfavourable to this hypothesis; and “since most of these branches, whether “ marine, volcanic, or mixed, preserve nearly the same external characters, directions, and parallelism;” it appears highly probable, that they have not pre-existed as hills in another state, but owe their elevation to the expansive force of fire; and that the same lava which appears in so many places lies also under all the limestone hills, of which indeed there are evident indications.

Several modern travellers have described the strata of granite mountains; but neither in their descriptions nor drawings have I been able to find satisfactory evidence of this arrangement; nor have I observed it in nature. A liquid mass swelled by heat must crack in cooling. Granite seems to me to have cracked most frequently like the *basalte en tables*; and these flat masses have been taken for strata. A stratum, consisting of proper materials to form whinstone or granite, may have been exposed to the necessary degree of heat, and possibly have undergone this change without much relative local derangement. Should such a stratum be discovered, it would afford no proof of the stratification of the great mountains of granite or shapeless whinstone, which, in consequence of its nu-

merous fissures in all directions, sometimes assumes enough of this appearance to impose on an unwary eye.

One consequence of these observations is too important to be omitted. They lead us to reject the common division of mountains into primary and secondary. The chains of granite, schistus, and limestone, must be all coeval; for if the central chain of the Alps burst as a body expanded by heat from the bowels of the earth, it reared the bordering chains at the same effort. But it must be recollected, that the mountains no longer wear their original form, vallies having been cut between and through them, and various other effects of dilapidation having taken place. It is by no means difficult to understand why no exuviae of organized bodies are found in these imaginary primitive mountains. Rising from a great depth, they threw aside the superficial accumulations of the ancient ocean. What was deepest is therefore now most central; and what lay on the surface now skirts the high interior chains. Hence the strata rest indifferently on granite, basalt, or lava; all which substances derive from their situation an equal claim to be regarded as primordial materials. It is a little surprizing, that this inveterate error, which has effectually barred the way to all great discoveries in geology till of late *, should have prevailed so long: for, 1. it is well known, that granite is sometimes found enclosing pieces of schistus †; nor are long stretches of slate uncommon in mountains of granite ‡. Now, how can a secondary be so enveloped in a primitive rock? and how easy is this to be understood, if we suppose granite as a fused mass raising, rending,

* Till Dr. HUTTON's Theory of the Earth, Edinb. Transf. Vol. I. appeared.

† BORN's Letters, p. 207, 208.

‡ HAIDINGER, *l. c.* p. 18.

and shivering the incumbent strata, while its heat hardened them into laminated stone. 2. Supposing granite mountains previously existing in the ancient ocean, the inclination of the incumbent strata, and their disarrangement is such that they could never have been deposited as they appear at present; they would have been much more horizontal in their direction. It seems impossible to attribute the disorderly deviation, which is so general in the mountains of slate, &c. from that position which all sediments from water assume, to any thing but a force lifting from below, and sometimes bursting through.

It is moreover certain, that all these lifting masses, from granite to acknowledged lava *, are found squeezed up through fissures formed in the strata by their own expansion. This, and not the infiltration of water, as M. DE SAUSSURE would persuade us †, appears to be the true origin of such veins of granite.

* FERBER, *l. c.* p. 51.

† *Voyages dans les Alpes*, 4to, I. 532—536. The whole passage well deserves the notice of those who are interested in these enquiries. Vertical strata, in one instance, lying against the foot of a granite mountain, are divided by oblique fissures, full of granite. This naturalist supposes them to have filled up gradually by the rain water dissolving particles of granite, carrying them down and depositing them in the form of granite again; two operations which one may safely deny to rain water the power of performing. Other insuperable objections to this theory start up at every step in the description. If water can dissolve any, it is surely but a very small part of all the ingredients of granite. Now, suppose a fissure full of such a solution; the water is, I suppose, to evaporate, and the crystallization to take place; the crystals must be small, on account of the small quantity of matter to form them, and a succeeding solution can only yield another crop of small crystals, it will not enlarge those already formed; but we are told, that the crystals of granite in the crevices in question are remarkably large. This has always appeared to me a chemical demonstration of the falsehood of a very common supposition, that the crystals often occurring in the cavities of
the

the amygdaloides rocks have been formed by the infiltration of water. The crystals are frequently of so large a size that you can by no means suppose the quantity of water, at any one time existing in the cavity, could have held the solid matter, of which they consist, in solution. Now, I think, it is contrary to all our experience in chemistry, to suppose crystals built up by successive operations. If upon crystals of nitre I pour a solution of the same salt, the former crystals will not be enlarged and amended, but a new set will be formed; so successive quantities of water, passing through these cavities, ought to form successive sets of very small crystals. Neither can I imagine, what causes can produce within these cavities a deposition of the matter once dissolved by the water. It is not cooled; it does not evaporate; it loses no fixed air; it comes in contact with no new matter, whose attraction may overpower the attraction of the water.

The divisions, "rather marked out than formed, which cross each other irregularly (p. 533.), and indicate an incipient retraction," are much more consistent with a simultaneous congelation than a gradual apposition; and the granite is the same as that of the contiguous hill in the colour and appearance of its constituent parts. This coincidence is a striking fact.

In truth, the philosophers who attribute the formation of granite to water seem not to have advanced a step in their proof beyond the equivocal circumstance of its being a crystallized mass.

